Too Hot to Handle

The truth about high burnup spent fuel

The problem with deciding 'in principle' to support new nuclear power stations is that once the actual details emerge, however troublesome, the Government will remain committed, and will be inclined to ignore them. In advance of detailed examination of the proposals of the nuclear industry the Government has reasserted its belief that new nuclear power stations would pose very small risks to safety. In fact the entire public consultation exercise seems to have been designed to protect the nuclear industry from proper scrutiny, and this 'keep it vague' method is continuing.

A good example is the way in which we as taxpayers are being 'locked in' to taking responsibility for the long-term management of highly radioactive waste from new nuclear power stations without any clear idea of the implications. The high burn up fuel proposed for new reactors uses more enriched uranium, and leaves it in the reactor for longer. This gets more output from the fuel, but increases the dangers of radioactive releases as the fuel cladding gets thinner. This increased danger persists throughout its storage and disposal.

The Government says that before it grants consent for new nuclear reactors it

> "will need to be satisfied that effective arrangements exist or will exist to manage and dispose of the waste they will produce". [1]

This approach has been denounced by the International Atomic Energy Agency as 'too vague to provide the required certainty'. In March 2007 the IAEA warned that Britain must not go ahead with a new generation of nuclear power stations until it has a "clear and robust" plan in place for dealing with the twin problems of decommissioning and waste treatment. The agency's executive director said:

"The spent-fuel issue is the most critical one for nuclear. It will not develop if there is not a credible and satisfactory answer to the management of spent fuel and one which is convincing for the public." [2]

The Government is currently consulting on their guidance notes for funded decommissioning. (consultation ends May 12th 2008) Operators of new nuclear power stations are to have secure financing arrangements in place to meet the full costs of decommissioning and their 'full share' of waste management costs. This should not be mistaken as a plan, let alone one which is clear and robust. In particular it avoids examining the worrying implications of on-site storage and subsequent direct disposal of high burnup spent fuel to underground repositories.

A fixed unit price payable to the Government for taking ownership of and responsibility for an operator's spent fuel is to be based on "a conservative estimate of the costs of disposal of the spent fuel in a geological disposal facility." It will cover the risk that the eventual costs of building a geological disposal facility to dispose of spent fuel are higher than estimated, and their non-availability at the time agreed. [3]

In order to encourage investment in new nuclear power stations the Government will signal in advance what the fixed spent fuel disposal charge is likely to be. It is probable that the spent fuel issue will be brazened out with vague reassurances rather than examined openly and honestly. If for short term political expediency a long term burden is passed on to future generations, with no certainty that sufficient funds will be available, it will violate the principles of 'sustainable development'.

The Pressure for High Burnup

Behind the skilled public relations about new nuclear reactor designs being safer and more advanced than existing designs lays a harsh fact. The nuclear industry, starved of orders for the last twenty years, is frantically trying to compete in a liberalized electricity market by cutting costs, both in new designs and the operation of existing reactors. The high burnup use of fuel, known as ‘optimisation,’ is reducing safety margins and splitting opinion within the industry. High burnup fuel means there is less fissile plutonium left, further reducing the viability of reprocessing.

For economic reasons new nuclear reactors will use uranium once, and spent fuel will be declared to be waste. This means abandoning the fantasy of a plutonium economy using fast breeder reactors in the numbers required to make a difference to climate change. But it also means that spent fuel from new reactors is going to be far more hazardous and problematic to manage than Britain’s existing spent fuel.

The Government’s policy that it is “technically possible and desirable to dispose of both new and legacy waste in the same geological disposal facilities” is unsupported, plain wrong, and will not survive scrutiny.

The consequences of higher burnup spent fuel have been pointed out by the IAEA. [4]

> “The higher burnup of fuel has a significant impact on the choice of the storage option and on the design of storage systems, due to the increased decay heat, inter-alia, which is roughly proportional to burnup, imposing a higher cooling load to the storage system.”

The 1999 liberalisation of the energy market in Europe put further pressure on Electricité de France (EDF) to become more competitive and resulted in the testing of higher burn up fuel. The European Pressurised water Reactor (EPR) has been ‘re-engineered’ as a result of the same demands. Originally designed as a 1495 MWe reactor based on the Framatome N4 and the Siemens KONVOI, analysis showed that to be competitive the cost per kilowatt hour would have to be reduced by an additional 10%.

An “optimization” study suggested that such a decrease in cost could be achieved if there was a 15% increase in the reactor’s power, fuel was enriched to up to 4.9% uranium235, and spent fuel discharged at a burnup of 60,000 MegaWatt days per tonne of Uranium. This compares with Sizewell B which has a fuel burnup of only 33,000 MWd/tU, and the Framatome N4 originally designed to use 39,000 MWd/tU burnup fuel (now raised in operation to 52,000 MWd/tU).

By 2004 it was claimed [5]: “The EPR….uses the best nuclear fuel in order to obtain the maximum energy. In doing so, it produces less waste.” Its manufacturers currently claim that [6] “Its design is based on experience from several thousand reactor-years of light water reactor operation worldwide.”

‘Higher than expected rates of oxidation’ of zircalloy fuel cladding at high burnups [7] have prompted the search for better alloys. It is, however, too soon to say how the addition of 1% niobium will affect the durability of high burnup fuel. [8] EDF is about to experiment using fuel to a burnup of 62,000 MWd/tU in 20 earlier reactors, so the truth is that the specific dangers associated with such fuel, in operation and storage, have not yet been experienced. Despite Westinghouse problems with high burnup the UK is asked to accept 60,000MWd/tU spent fuel from its AP1000 PWR design.

As for producing less waste, while it is true that as the enrichment and the burn-up rate of the fuel is higher the volume of spent fuel is lower; this comes at a very heavy price. High burnup spent fuel will be hotter and more radioactive and therefore take more space within a store. It is partly for this reason that the industry has lobbied for charges to be fixed in advance for taking away and disposing of their spent fuel.

As the temperature for dry storage must be maintained below design limits, the heat of the spent fuel needs to be decayed to a sufficiently low level by cooling in a storage pool for several years.

> "This cooling period is dependent upon the fuel's burnup (for a higher burnup, more than a decade of cooling in the pool may be required)". [9]

It is unclear whether the EPR with seven years storage capacity in the spent fuel pool within the reactor building has adequate provision for high burn up spent fuel.

When it is removed from the cooling ponds certain problems of high burnup fuel actually intensify. The cladding of spent nuclear fuel above 45,000MWd/tU is vulnerable to the formation of radial hydrides after the spent fuel is removed from the spent fuel pool for dry storage or transportation. [10]

This matters because if these hydrides develop due to the rate of cooling, the duration of drying, and the hydrogen content, the cladding is prone to failure, especially during a handling accident in which it is dropped. [11]

In the USA the Yucca Mountain geological repository has been delayed and the management of spent fuel has become a nationwide preoccupation. Waste from over 100 nuclear reactors that the federal government was meant to start accepting for burial (at a low fixed charge) ten years ago, is still at the reactor sites at least 20 years behind schedule. It is forecast to cost the US government at least $7 billion in settlements over the next few years.[12] As loaded dry casks increase fivefold in the decade to 2010, and reactor owners use higher burn up fuel, the Nuclear Regulatory Commission has expressed concern about high burnup spent fuel: [13]

> ".....there is limited data to show that the cladding of spent fuel with burnups greater than 45,000 MWd/MTU will remain undamaged during the licensing period. Limited information suggests increased cladding oxidation, increased hoop stresses and changes to fuel pellet integrity with increasing burnup up to and beyond 60,000 MWd/MTU. These burnup dependent effects could potentially lead to failure of the cladding and dispersal of the fuel during transfer and handling operations.

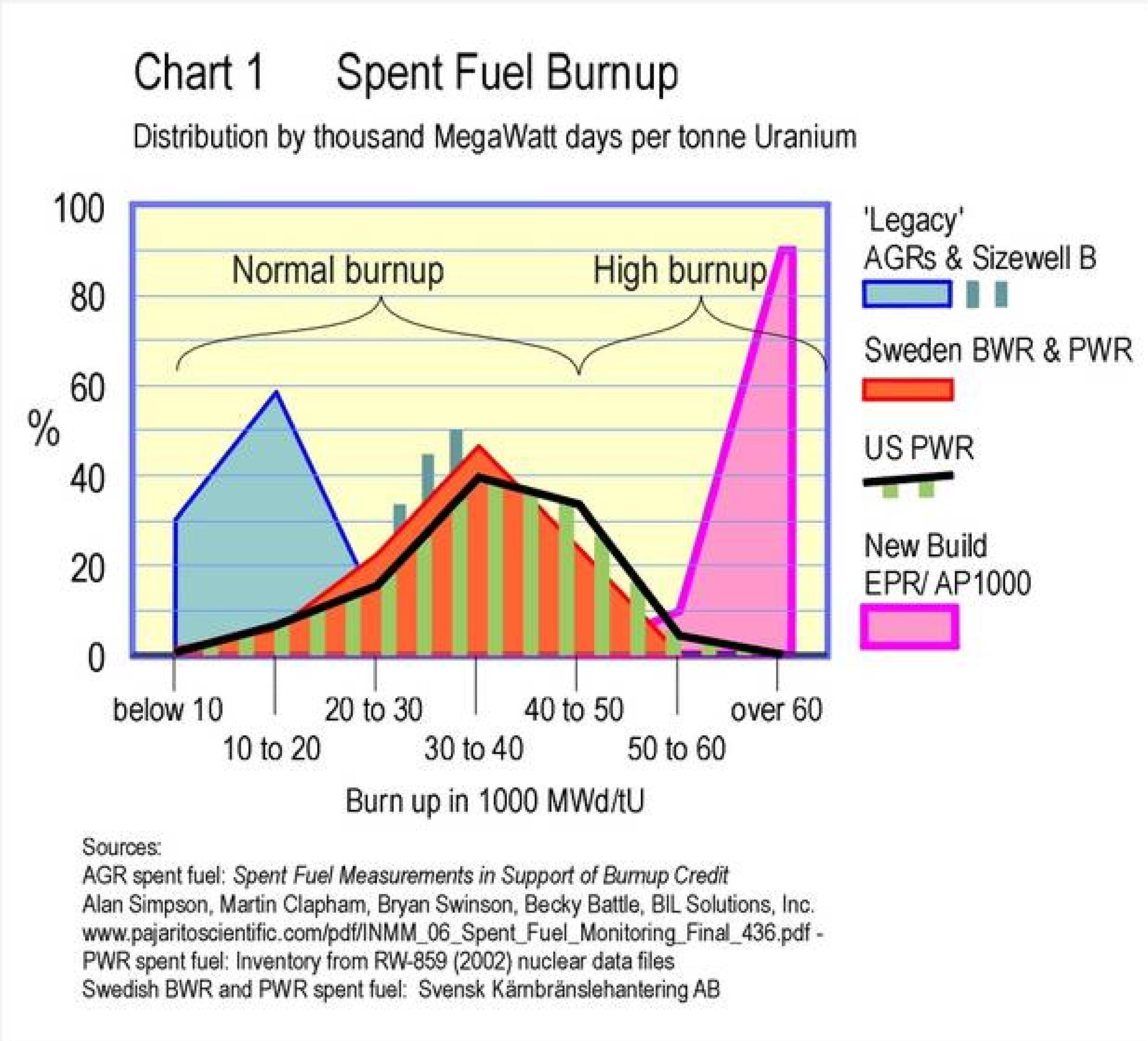
Safety fears about the longer term integrity of such fuel is becoming an international matter leading the IAEA to demand more research on fuel behaviour in dry storage as essential.[14]

> "In particular...high burnup fuels and mixed oxide (MOX) fuels will need to be carefully assessed in the context of ensuring long term storage safety."

The high burnup of the EPR spent fuel leads to higher fissile contents. Higher heat loads require packaging with improved heat transfer capacity, and new materials that can withstand the effect of higher temperatures on components and materials. Coping with this is still at an experimental stage. The high initial enrichment results in spent fuels with higher gamma and neutron radiation levels than current fuels, so it will require greater shielding, as AREVA themselves acknowledge: [15]

> "....to work towards achieving the 'low as readily achievable' criterion in relation to the control of radiation doses to workers and the public........efforts are being focused on developing enhanced shielding designs.

United States official estimates for the heat output of 50,000 MWd/tU PWR spent fuel suggest that 50 yrs after withdrawal from the reactor each tonne emits at least 800 W. The heat output from four 60,000 MWd/tU EPR or AP1000 fuel assemblies would at this stage exceed 2,000W. For deep underground disposal the temperature requirements of the Nirex PWR packaging concept limit the decay heat in one canister (each with four fuel assemblies) to 1,700 W. [16]



The chart above illustrates the very dramatic difference between the burn-up and hence the heat output of Britain's 'legacy' spent fuel, and that likely to arise from a programme of new nuclear power stations using 'high burnup' fuel. AGR spent fuel ranges typically from 5,000MWd/tU to 25,000MWd/tU, while the Sizewell B PWR fuel averages about 30,000MWd/tU. The orange area illustrates the range of BWR and PWR spent fuels that SKB, the company planning a deep geological repository in Sweden has to accommodate.

Three quarters of Swedish fuel has a burn up of below 40,000MWd/tU but as SKB acknowledged in 2007: [17]

> "Now that the nuclear power companies have announced that they want to increase the average burnup for both PWR and BWR fuel to 60 MWd/kgU, additional calculations are also required of…..radionuclide inventory, decay heat and criticality. New leaching tests also have to be done."

This is important because the SKB repository concept has been adopted by the Nuclear Decommissioning Authority as the 'reference repository' for Britain in order to demonstrate the feasibility of deep geological disposal. Setting aside the great uncertainities in this approach, the Swedish concept could at least theoretically accommodate the cooler low burnup spent fuel comprising Britain's 'legacy'.

About 20% of the US spent fuel from PWRs to be accommodated in the Yucca Mountain geological repository has a burnup of over 45,000MWd/tU, requiring a more generous spacing of the deposition tunnels to allow a greater volume for heat dissipation. The French agency looking at the deep disposal concept [18] already foresees major difficulties with the long term storage of MOX fuel, tied to its heavy thermal load (average MOX fuel burnup is 'only' 47,000 MWd/t.)

What is apparent is that high burnup spent fuel from the EPR or AP1000 cannot be accommodated in the NDA 'reference repository' as presently designed. High burn-up spent fuel will either have to be stored for longer than 50 years (probably over 70 years) or emplaced with fewer fuel assemblies in each canister, requiring a larger repository, both involving greater public expense per tonne of spent fuel.

There is no evidence that this has been taken into consideration by the government or its agencies. Indeed, in February 2007 NIREX acknowledged that 'no calculations had yet been performed for the heat output from EPR canisters', and consequently estimated the impact on a deep underground repository of the spent fuel from a programme of 7 EPRs on the assumption that 4 fuel assemblies could be placed in each canister.[19]

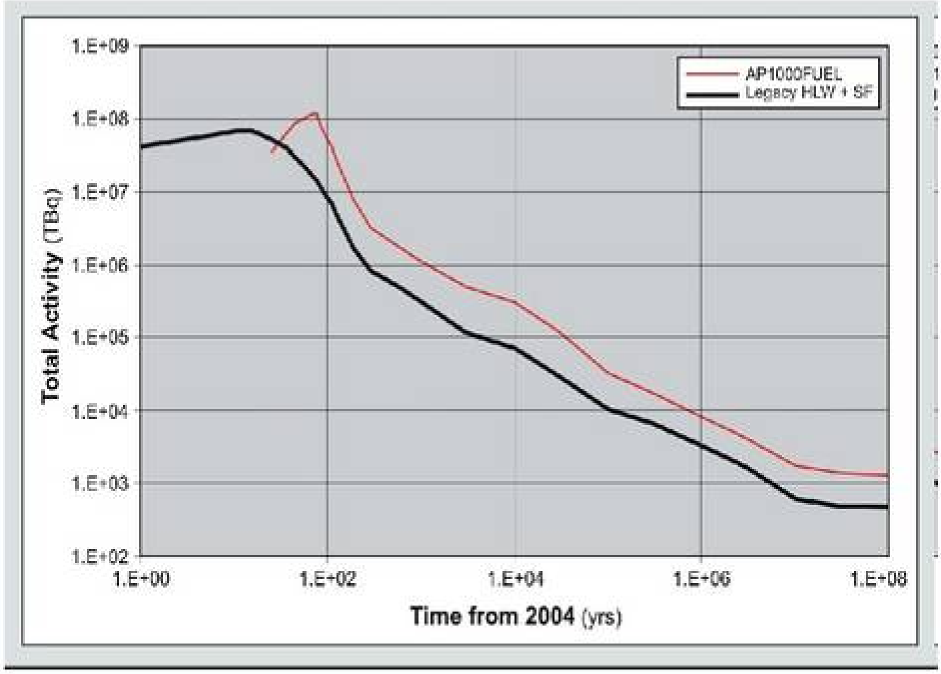
Chart 2, overleaf, reproduces Fig 5 from a NIREX study of radioactive waste implications associated with new build reactors[20], it "compares the time evolution of the total activity in new build SF with that from HLW and SF from the legacy power programme"

Exactly the same data has been used to draw the chart underneath. This shows the first 200 years of spent fuel management, but on an arithmetic scale. In order to form a sound judgment about the additional amount of radioactivity to be dealt with, the new build radioactivity has been added to the legacy radioactivity.

The vertical line indicating the year 2075 shows the situation at the earliest time that it is envisaged the direct disposal of spent fuel deep underground could occur, should it prove feasible. At that time the radioactivity of the more demanding high burnup spent fuel from new build would be over six times the radioactivity from Britain's legacy spent fuel and HLW (High Level radioactive Waste). Radioactivity from new build remains at six times that from the legacy spent fuel over the next 130 years.

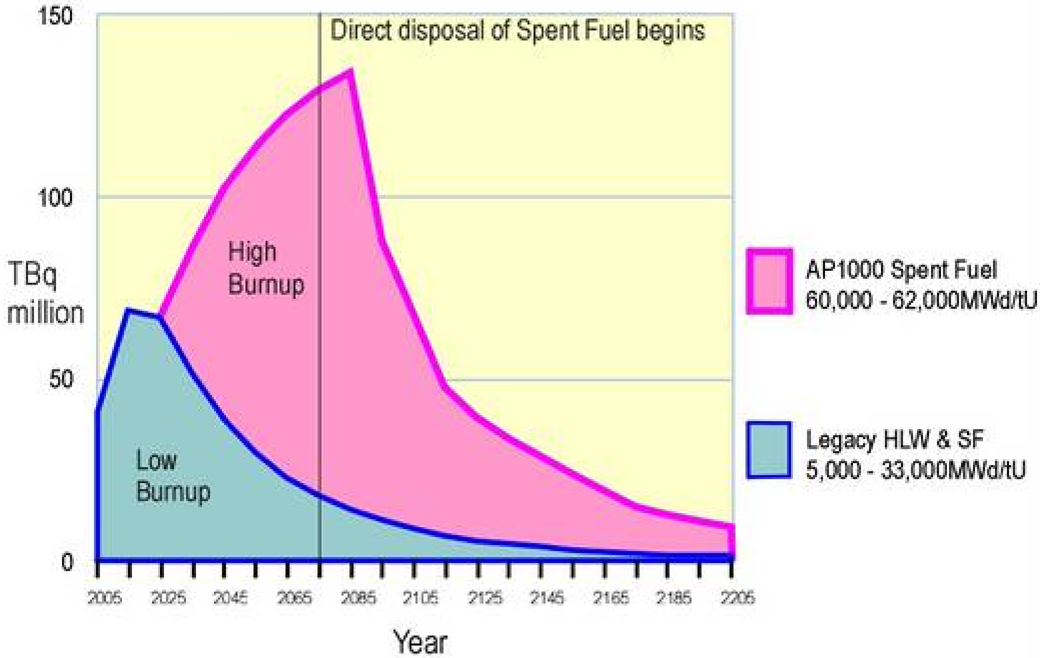
Chart 2 Radioactivity from Legacy and New Build Nuclear

As presented by NIREX in 'the Gate Process' Fig 5 (logarithmic scale)



Radioactivity from Legacy and New Build Nuclear

Same data for the first 200 years redrawn on an arithmetic scale showing new build spent fuel added to legacy waste



The nuclear industry says new nuclear build in the UK should not be dependent on a solution to the waste issue being found. "If new build does occur, a repository dealing with legacy wastes could readily accommodate the smaller volumes of easier-to-handle wastes from that new generation of nuclear plants." [21]

Conclusions

Government tolerance of this wilful misinformation will forfeit public trust as the truth emerges. Official ignorance about such matters is inexcusable, particularly in the context of IAEA warnings. The Government has already acceded to nuclear industry demands for a 'fixed charge' to take ownership of its spent fuel and dispose of it. Uncertainties about the safety and feasibility of direct disposal of high burnup spent fuel will take decades to address. In this context **any** level of charge fixed now would expose future taxpayers to the risk of huge uncovered liabilities while representing a deliberate present day incentive to the nuclear sector.

- Direct disposal of spent fuel in deep underground repositories is an unproven concept.
- The Swedish repository adopted by Britain to establish the feasibility of the concept for British legacy waste was designed for 'normal' burnup spent fuel. (99.8% of Swedish spent fuel is below 50,000MWd/tU)
- The vendors of new nuclear reactors, in particular the EPR and the AP1000, want our Government to agree to take high very burnup spent fuel (over 60,000MWd/tU) off their hands for a charge fixed in advance of technical and scientific confidence.
- Such fuel is more demanding at every stage of the nuclear cycle from the reactor itself, subsequent cooling in ponds, through drying and storage in dry casks to eventual burial. It will increase potential worker and public exposure to radiation.
- There is very little experience of spent fuel over 60,000MWd/tU, and materials for its safe containment after the cooling pond are still at an experimental stage.
- Such fuel will need several decades additional cooling time, or to be spaced out more widely in underground repositories, increasing their 'footprint'.
- Such are the uncertainties about high burnup spent fuel, **any** level of fixed disposal charge would expose the future taxpayer to the risk of huge uncovered liabilities.

According to the Royal Society if a new nuclear power programme is established the need for a separate disposal site for newer HLW would remain.[22]

There are compelling reasons to shield any programme for managing Britain's legacy waste from the highly uncertain and risky consequences of disposing of high burn-up spent fuel from a new nuclear power programme.

March 10th 2008

Transedw Lodge
Hundred House
Llandrindod Wells
Powys LD1 5RY

Tel: 01982 570362
Email: hughrichards@gn.apc.org

REFERENCES

1 *MEETING THE ENERGY CHALLENGE* Department for Business, Enterprise and Regulatory Reform (page 99)

2 Britain gets nuclear waste warning from energy chiefs Independent 02 March 2007

3 *The Energy Bill 2008 Consultation on Funded Decommissioning Programme Guidance for New Nuclear Power Stations* (page 65)

4 *Selection of Away-From-Reactor Facilities for Spent Fuel Storage, A Guidebook*. IAEA Tecdoc 1558 Sept 2007, Para 2.1.4, Page 7 and footnote 3.

5 AREVA, the French 90% state-owned company that merged Framatome and Cogema, claim in a PRESS RELEASE October 22, 2004

6 http://www.areva-np.com/scripts/info/publigen/content/templates/show.asp?P=863&L=US

7 NRC INFORMATION NOTICE 98-29: PREDICTED INCREASE IN FUEL ROD CLADDING OXIDATION NUCLEAR REGULATORY COMMISSION; OFFICE OF NUCLEAR REACTOR REGULATION WASHINGTON, D.C. 20555-0001 August 3, 1998

8 SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION TOPICAL REPORT BAW-10186P-A, REVISION 1, SUPPLEMENT 1, "EXTENDED BURNUP EVALUATION" FRAMATOME ANP PROJECT NO. 693 June 2003

9 *Operation and Maintenance of Spent Fuel Storage and Transportation Casks/Containers*. Page 4, Para 2.2.1. Removal of decay heat. IAEA, VIENNA, 2007. IAEA-TECDOC-1532

10 *Cladding Considerations for Transportation and Storage of Spent Fuel*, Nuclear Regulatory Commission Interim Staff Guidance (ISG)-11, Rev. 3, November 17, 2003.

11 R. S. Daum, S. Majumdar, Y. Liu, and M. C. Billone, *Radial-hydride Embrittlement of High-burnup Zircaloy-4 Fuel Cladding*, Journal of Nuclear Sci. and Tech., Vol. 43, pp. 1054–1067, April 2006

12 *As Nuclear Waste Languishes, Expense to U.S. Rises*. New York Times, February 17, 2008

13 NUREG-1567 Standard Review Plan for Spent Fuel Dry Storage Facilities, Final Report March 2000 page 6-15

14 Management of Spent Fuel from Nuclear Power Reactors; Proceedings of an International Conference organized by the IAEA in cooperation with the OECD Nuclear Energy Agency. VIENNA, 19– JUNE 2006 Summary, Page 3

15 *Anticipating Future Needs for the Transport and Storage of Spent Fuel from Evolutionary Nuclear Power Reactors*. H. ISSARD TN International, AREVA group, St. Quentin-en-Yvelines, France; in *Management of Spent Fuel from Nuclear Power Reactors*; Proceedings of an International Conference organized by the IAEA in cooperation with the OECD Nuclear Energy Agency. VIENNA, 19– JUNE 2006, page 342.

16 Initial state report for the safety assessment SR-Can, Svensk Kärnbränslehantering AB, October 2006 Page 41

17 Technical Report TR-07-12 SKB RD&D Programme 2007 page 10

18 CNE - National Evaluation Commission for research on the management of radioactive wastes Rapport d'Evaluation No. 6, juin 2000.

19 *NIREX The Gate Process: Preliminary analysis of radioactive waste implications associated with new build reactors* February 2007 Number: 528386

20 *NIREX The Gate Process: Preliminary analysis of radioactive waste implications associated with new build reactors* February 2007 Number: 528386

21 The Nuclear Industry Association 'Nuclear Future – Vol.04, N01' January 2008

22 Royal Society Submission to the House of Lords Select Committee on Science and Technology inquiry into The Management of Nuclear Waste, Feb 1998 Page 7